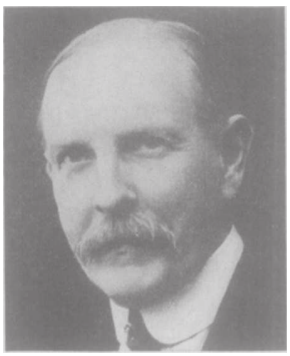
The Work of the Institute in Standardization

By A. E. Kennelly, President A.I.E.E. 1898-1900

An historical outline of the standardization activities of the A.I.E.E. is recorded in this article by a past-president who was chairman of the Institute's first standardization committee and who continuously since the appointment of that committee has been actively engaged not only in the standardization work of the Institute, but also in international standardization of electrical units.

THE American Institute of Electrical Engineers has had a remarkable history of standardization activities during the half century that has intervened since its founding in 1884. These activities may be divided into 3 categories: (1) work on units, standard definitions, and nomenclature relating to basic sciences underlying electrical engineering, beginning in 1890; (2) work on similar projects relating to applied science, engineering, and technology, beginning in 1898; and (3) work on projects relating to production and manufacture connected with electrical engineering, beginning in 1920. It is the purpose of this article to offer a brief outline of those activities.



First Recorded Action

The first action of the Institute in relation to standard units occurred on June 17, 1890 (v. 7, p. 89–90[1]) when Prof. F. G. Crocker offered a resolution "that the name of Henry should be given to the practical unit of self-induction." This resolution was adopted and a committee was appointed to report upon the recommended magnitude of the unit. The committee reported January 20, 1891 (v. 8, p. 31) in favor of the magnitude in the practical electromagnetic unit series, *i. e.*, 10^9 c.g.s. magnetic units of inductance, a magnitude already known as the "quadrant," or the "secohm." It is thus interesting to notice that the first standardization recommendation of the Institute was in favor of the name "henry" for the practical unit of inductance.

The Units and Standards (U.&S.) Committee

About the same date (June 1891) the Institute appointed its first standing committee on standardization—the committee on "units and standards." The members of this committee were: A. E. Kennelly, *chairman*, F. B. Crocker, W. E. Geyer, G. A. Hamilton, and G. B. Prescott, Jr.

The U.&S. committee made its first report on June 20, 1891, suggesting that the Institute should recommend to the next International Electrical Congress (Chicago 1893) 4 practical electromagnetic units as follows:

1. A practical unit of magnetomotive force equal to $1/4\pi$th ampere turn.
2. A practical unit of magnetic flux equal to 10^9 c.g.s. magnetic units
3. A practical unit of flux density equal to 10^9 c.g.s. magnetic units per square centimeter.
4. A practical unit of reluctance, in conformity with units 1 and 2.

It was suggested also that appropriate names should be assigned to these units; but no names were offered. The report was forthwith accepted by the Institute (v. 8, p. 536).

The Institute had also appointed a "standard wiring table committee," to assign the linear resistance of standard-conductivity copper wire of British and American gauges (B.W.G. and A.W.G. or B.&S.) and at standard temperatures (20, 50, and 80 deg C). The personnel was F. B. Crocker, *chairman*, G. Duncan, W. B. Geyer, A. E. Kennelly, G. B. Prescott, E. W. Rice, Jr., M. P. Roberts, H. J. Ryan, W. Stanley, Jr., and S. S. Wheeler. The committee presented a report in 1893 (v. 10, p. 21–5), and prepared a wire table (v. 10, opposite p. 668) part of which is reproduced on the next page.

International Electrical Congress, 1893

A committee also was appointed to prepare a provisional program for the chamber of delegates of the forthcoming International Electrical Congress of Chicago (1893) in regard to units, standards, and nomenclature. Its personnel was: Carl Hering *chairman*, W. A. Anthony, and A. E. Kennelly. The committee reported in January 1893, including the U.&S. committee report of June 1891 referred to previously (v. 10, p. 1–16).

The Chicago congress voted against adopting magnetic units in the practical series, and recommended the retention of the magnetic units in the c.g.s. system, for the present without names. However, the congress adopted the name "henry" for the practical unit of inductance, at the value of 10^9 c.g.s. magnetic units. It also drew up specifications for the practical unit standards under the name of "international electrical units."

In view of the actions of the Chicago congress with respect to magnetic units, the U.&S. committee of the Institute brought in a report November 15, 1893 (v. 11, p. 48–9), recommending the Institute's provisional adoption of the following 4 names for c.g.s. magnetic units; "gilbert" for magnetomotive force, "weber" for flux, "oersted" for reluctance, and "gauss" for flux density. At the first reading, the report was laid on the table; but at a subsequent meeting, on March 21, 1894, the report was re-

1. All bibliographic references refer to A.I.E.E. Transactions.

considered (v. 11, p. 124) and, after discussion, was provisionally adopted (p. 132).

The U. & S. committee also recommended to the Institute that the United States Congress be urged to pass a bill for legislative action on the international series of electrical units adopted by the Chicago electrical congress (May 1894, v. 11, p. 189–90). This resolution was adopted.

In 1894, differences of opinion presented themselves among the members of the Institute as to the meaning of the term "inductance." With a view to securing international agreement on the definition of this term, the U. & S. committee consulted the Institution of Electrical Engineers in London, the Société Française des Electriciens in Paris, and the Elektrotechnischer Verein also the Physikalisch-Technische Reichsanstalt in Berlin. On the basis of the replies received, the U. & S. committee recommended that the Institute should adopt the term "inductance" as meaning a coefficient of induction, with symbol L. The report was adopted May 1894 v. 11, p. 253–60). The correspondig present definition of the term reactance" then proposed by Doctor teinmetz, also was adopted forthith.

In December 1894, the U. & S. comnittee reported to the Institute (v. 1, p. 827–9), citing the act of Conress H.R. 6,500, legalizing, in the Jnited States, the international lectrical units adopted by the Chicago congress.

Standards of Luminous Intensity

On January 19, 1897 (v. 14, p. 90) the U.&S. committee recommended to the Institute that the amylacetate Hefner-Alteneck lamp should be adopted temporarily as standard of luminous intensity or candlepower, under standard specifications. The committee recommended also that the Lummer-Brodhun photometer screen be adopted for measuring the mean horizontal intensity of incandescent lamps, the lamp being rotated about its vertical axis at a speed of about 2 turns per second. It was recommended further that the mean spherical candlepower of a lamp should be used as far as practicable.

[Supplement to Transactions October 1893.]

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

COPPER WIRE TABLE.

Giving weights, lengths, and resistances of cool, warm, and hot wires, of Matthiessen's standard conductivity, for both A. W. G. (Brown & Sharpe) and B. W. G.

GAUGES To the nearest fourth significant digit.				WEIGHT.				LENGTH.				RESISTANCE.					
A.W.G.	B.W.G.	Diameter.	Area.	Lbs. per foot.	Lbs. per Ohm.			Feet per lb.	Feet per Ohm.			Ohms per lb.			Ohms per foot.		
B. & S.	Stub's	Inches.	Circular mils.		@ 20° C.	@ 50° C.	@ 80° C.		@ 20° C.	@ 50° C.	@ 80° C.	@ 20° C.	@ 50° C.	@ 80° C.	@ 20° C.	@ 50° C.	@ 80° C.
0000		0.460	211,600	0.6405	13,090	11,720	10,570	1.561	20,440	18,290	16,510	0.00007639	0.00008535	0.00009459	0.00004893	0.00005467	0.00006058
	0000	0.454	206,100	0.6239	12,420	11,120	10,030	1.603	19,910	17,820	16,080	0.00008051	0.00008996	0.00009969	0.00005023	0.00005612	0.00006220
	000	0.425	180,600	0.5468	9,538	8,537	7,704	[illegible]	[illegible]	15,620	14,090	0.0001048	0.0001171	0.0001298	0.00005732	0.00006404	0.00007097
												[illegible]	0.0001357	0.0001504	[illegible]		
			[illegible]	0.00004843	[illegible]	[illegible]	0.00006045	20,650	1.545	[illegible]	[illegible]					[illegible]	[illegible]
[illegible]		0.003965	15.72	0.00004759	0.00007210	0.00006454	0.00005824	21,010	1.519	1.359							
39		0.003531	12.47	0.00003774	0.00004545	0.00004068	0.00003671	26,500	1.204	1.078	0.9726	22,000	24,580	27,240	0.8304	0.9277	1.028
40		0.003145	9.888	0.00002993	0.00002858	0.00002559	0.00002309	33,410	0.9550	0.8548	0.7713	34,980	39,080	43,320	1.047	1.170	1.296

The data from which this table has been computed are as follows:—Matthiessen's standard resistivity, Matthiessen's temperature coefficients, specific gravity of copper = 8.89. Resistance in terms of the international ohm.
Matthiessen's standard 1 metre-gramme of hard drawn copper = 0.1469 B. A. U. @ 0° C. Ratio of resistivity hard to soft copper 1.0226.
1 " soft " = 0.14365 B. A. U. @ 0° C. One B. A. U. = 0.9866 international ohms.
1 " soft " = 0.141729 international ohm @ 0° C.
Temperature coefficients of resistance for 20° C., 50° C., and 80° C., 1.07968, 1.20625, and 1.33681 respectively. 1 foot = 0.3048028 metre, 1 pound = 453.59256 grammes.
Although the entries in the table are carried to the fourth significant digit, the computations have been carried to at least five figures. The last digit is therefore correct to within half a unit, representing an arithmetical degree of accuracy of at least one part in two thousand. The diameters of the B. & S. or A. W. G. wires are obtained from the geometrical series in which No. 0000 = 0.4600 inch and No. 36 = 0.005 inch, the nearest fourth significant digit being retained in the areas and diameters so deduced.
It is to be observed that while Matthiessen's standard of resistivity may be permanently recognized, the temperature coefficient of its variation which he introduced, and which is here used may in future undergo slight revision.

F. B. CROCKER, W. E. GEYER, G. A. HAMILTON, A. E. KENNELLY, Chairman, } Committee on "Units and Standards."

Standard copper wire table of linear resistivity prepared by an Institute committee in 1893 and published in the TRANSACTIONS (v. 10, opposite p. 668) (Top and bottom portions only are shown)

Committee on Standardization

Concurrent A.I.E.E. meetings were held in New York and Chicago (January 26, 1898, v. 15, p. 2–32) devoted to the topical discussion of "The Standardization of Generators, Motors, and Transformers," led by F. B. Crocker in New York, and B. J. Arnold in Chicago. As a result of these discussions, the A.I.E.E. council shortly afterward appointed a "committee on standardization" with the following membership: F. B. Crocker, *chairman*, C. T. Hutchinson, A. E. Kennelly, J. W. Lieb, C. P. Steinmetz, L. B. Stillwell, and E. Thomson. The influence of this committee in electrotechnics and engineering has been so important down to the present day that a brief account of its aims should be given here. The policy of the committee originally planned has remained fairly uniform throughout, as an inspection of its various successive reports will show.

The committee sought to avoid all standardization of sizes or dimensions of electrical machinery. It aimed to define and state in as simple language as practicable, the nature, characteristics, behavior, rating, and methods of testing of electrical machinery and apparatus, particularly with a view to setting up acceptance test standards for electrical industry.

The first report of the standardization committee was adopted by the Institute June 26, 1899 (v. 16, p. 255–68); it also was printed in the A.I.E.E. handbook for 1900, p. 124–36. It included the following subject headings: Efficiency, Rise of Temperature, Insulation, Regulation, Variation and Pulsation, Classification of Voltages, Overloads, etc. There was a considerable demand for the report in the industry from the date of its first appearance, and some 900 copies had been distributed by May 17, 1900 (v. 17). A second report of the standardization committee, revised and enlarged was presented at the A.I.E.E. convention in Great Barrington, Mass., June 20, 1902 (v. 19, 1902, p. 1076–91). After 1902, the successive reports of the committee were reprinted under the title "Standardization Rules of the A.I.E.E." When the A.I.E.E. constitution was amended in May 1907, the standardization committee was established as a standing committee of the Institute, and its name was changed to the "standards committee," which it remains to the present day.

International Electrical Congress at Paris, 1900

The units and standards committee recommended to the Institute May 17, 1900 (v. 17, 1901, p. 309–18) that at the forthcoming Paris congress, names should be advocated for 4 c.g.s. magnetic units provisionally adopted by the Institute in November 1893; also the principle of prefixes for them. The committee also recommended that the question of rationalizing them should be discussed. The committee report was adopted for presentation to the congress.

At the Paris congress, the chamber of delegates limited consideration to 2 c.g.s. unit names only: the "maxwell" and the "gauss." The name "maxwell" was assigned to the c.g.s. unit of magnetic flux, Φ, in accordance with A.I.E.E. recommendation; but there was some misunderstanding as to the unit receiving the name "gauss." The A.I.E.E. delegates believed that it had been adopted for flux density, B, as adopted provisionally by the Institute in 1893, and as advocated by them at Paris. They reported to the Institute in November 1900, that the name "gauss" had been adopted for flux density, B (v. 17, p. 543–7); but the official minutes of the congress, published in 1901, showed that the name "gauss" had been assigned to magnetic field intensity, H. In the English text of the congress preliminary report printed in the A.I.E.E. Transactions (v. 17, p. 552) "gauss" for field density was also ambiguous. This accidental misunderstanding led subsequently to considerable confusion in magnetic literature.

Establishment of the U.S. Bureau of Standards

The Institute endorsed in 1901 (v. 17, p. 615) bills then before the U.S. Congress for establishing a national standardizing bureau at Washington, D. C., "for the construction, custody, and comparison of standards used in scientific and technical work." This bureau, created shortly afterward, came to be known as the National Bureau of Standards, and has exerted a marked influence on science, engineering, and industry. Close connection has been maintained between the Institute's committees and the Bureau of Standards.

International Electrical Congress of St. Louis, 1904

The St. Louis congress was notable in the history of the Institute's work of standardization as being the last electrical congress held in America, and as having taken actions in its chamber of delegates that completely changed the procedure of international electrical congresses since 1904, in reference to electrical units and standards.

The congress met September 12–17, 1904, close to the Exposition buildings. The work was distributed under 8 sections, 2 for theory and 6 for applications. There were 3 volumes of transactions, containing 158 papers. The organization was prepared by the Institute. The president was Prof. E. Thomson; honorary vice-presidents: Ascoli, Crompton, Glazebrook, Gonzales, Gray, Lombardi, Perry, and Poincaré; vice-presidents: Arnold, Carhart, Goldsborough, Scott, and Stratton; general secretary, Kennelly; and treasurer, Weaver.

The chamber of delegates, in which 11 countries were represented, decided that it would not be desirable to undertake international standardization by the St. Louis congress. It unanimously recommended, however, that 2 international commissions should be established: (1) to consist of government representatives charged with the legal maintenance of electrical standards in the various

countries, to deal with such units and standards; and (2) to consist of representatives of various national electrotechnical societies, to deal with the standardization of electrical apparatus and machinery. These recommendations were adopted.

Commission 1 later came into operation as International Conferences on Electrical Units in 1905 at Berlin, and again at London in 1908. The last named was attended by government delegates from 24 countries. Important standardization work was accomplished at these conferences in reference to the maintenance of precise standards of legalized electrical units. In pursuance of this work, an international technical committee from the national laboratories of France, Germany, Great Britain, and the United States, met at Washington in 1910.

In October 1933, the Eighth International Conference of Weights and Measures at Sèvres, adopted a resolution assuming the continuation of the London conference of 1908. In that sense, therefore, commission 1 organized at the St. Louis congress of 1904, may be regarded as maintaining a continued existence.

International Electrotechnical Commission

Commission 2 organized at the St. Louis congress later came into operation as the International Electrotechnical Commission (I.E.C.). It was organized in 1905, under the auspices of Col. R. E. Crompton, who was an honorary vice-president of the St. Louis congress. Mr. C. Lemaistre was appointed its general secretary, with offices at 28 Victoria St., London. The first meeting of the I.E.C. was held at London, for organization, in 1906, when Lord Kelvin was elected the first president.

The I.E.C. is maintained by some 25 countries, each of which has a standing national committee with local officers. The work is divided among 18 technical advisory committees, holding meetings from time to time and reporting their decisions at successive general conventions. There have been 19 of these general conventions to date, in the cities of London (1906, '08, '19, and '24), Brussels (1910 and '20), Cologne (1911 and '13), Turin (1911), Paris (1912, '19, and '23), Zurich (1913), Berlin (1913), Geneva (1922), The Hague (1925), New York (1926), Bellagio (1927), and Copenhagen-Stockholm-Oslo in 1930.

The Institute has taken an active share in the maintenance of the U.S. national committee, and after 1908 kept a standing I.E.C. committee the chairmen of which have been F. B. Crocker, E. Thomson, C. O. Mailloux, A. E. Kennelly, D. C. Jackson, and C. H. Sharp. The international presidents have been Kelvin, Thomson, Budde, Leblanc, Mailloux, Semenza, Feldmann, and Enström. There have been 3 honorary presidents: Mailloux, Crompton, and Semenza. Among the advisory committees are those on the rating of electrical machinery, glossary of terms, units, symbols, voltages, etc.

The U.S. national committee of the I.E.C. includes representatives of the Institute, the American Society of Mechanical Engineers, the American Society for Testing Materials, the Electrical Manufacturers Association, several departments of the U.S. government, and the American Standards Association, the secretary of which, Dr. P. G. Agnew, is also secretary of the U.S. national committee of the I.E.C.

The standardization work of the I.E.C. and of its constituent national committees is basically in electrical engineering; however, owing to the close association of steam engines and hydraulics with electric generation, some I.E.C. technical committees deal with fields of mechanical and civil engineering, such as turbines and ratings of rivets.

Since the Bellagio meeting of 1927, the I.E.C. has taken steps to standardize the names and definitions of the c.g.s. magnetic units. Section B of advisory committee No. 1 for nomenclature on "electric and magnetic magnitudes and units" (E.M.M.U.) has held meetings at Stockholm (1930), London (1931), and Paris (1933) at which certain conventions have been recommended for eliminating ambiguity and confusion in international magnetic literature (I.E.C. Documents R.M. 77, 97, and 105). In this undertaking, the aid of the International Union of Pure and Applied Physics has been invoked, through that union's committee on symbols, units, and nomenclature (S.U.N.) which held a meeting at Paris in July 1932, devoted to the same topics.

At the Turin meeting of the I.E.C. in 1911, unanimous agreement was reached on the standard direction of phase advance in vector diagrams, and on the standard direction of inductive reactance in impedance vector triangles ($R + jX$) (v. 30, 1911, p. 2371).

Since 1911, the I.E.C. has been recognized as granting authorization for holding international electrical congresses. No such congresses have undertaken to establish new electrical units.

International Commission on Illumination (Commission Internationale de l'Eclairage)

This international body was the successor of the Commission Internationale de Photometrie, and has national committees in 15 countries. Its first meeting was at Berlin in 1913. Its central office is at the National Physical Laboratory, Teddington, England. Since 1913, the A.I.E.E. has appointed 3 representatives each year to the U.S. national committee of the I.C.I. The last meeting of the Commission was held at Cambridge, England, in 1931.

The I.C.I. undertakes to establish units, standards, and nomenclature in the science and technology of light and illumination. The president of the U.S. national committee is E. C. Crittenden, at the U.S. Bureau of Standards, and the secretary is G. H. Stickney, at Nela Park, Cleveland, Ohio.

American Standards Association (A.S.A.)

This organization, formerly the American Engineering Standards Committee (A.E.S.C.), has been aptly described as a "national clearing house for industrial standardization." It is composed of a

number of engineering societies, manufacturing associations, and operating or consumers associations. Its main purposes are to simplify and standardize production and construction, with the elimination of overlapping, reduplication, and waste. By establishing standards in sizes, specifications, and tests, it enables marked economies to be effected in manufacture and service. The A.E.S.C. was organized in 1919. In recent years, its name has been changed to the American Standards Association (A.S.A). Since 1920, the Institute annually has appointed representatives on the council of the A.S.A. The headquarters of the A.S.A. are in the Engineering Building, New York, N. Y., and its secretary is Dr. P. G. Agnew.

Scientific and Engineering Symbols and Abbreviations

The Institute took part in standardizing engineering symbols and abbreviations in 1926, under the auspices of the American Standards Association. Other sponsoring bodies were the American Association for the Advancement of Science, the American Society of Civil Engineers, The American Society of Mechanical Engineers, and the Society for the Promotion of Engineering Education. The chairman of the section committee was Dr. J. F. Meyer, and the secretary was Mr. P. S. Millar. Nine subcommittees were formed to cover different departments of the work. The subcommittee on mathematical symbols (project Z10f) had 14 members and Prof. E. V. Huntington was the chairman. This work was approved by the A.S.A. in January 1928. For purposes of amplification and revision the original committee is being continued but with some subdivision and reorganization of both scope and personnel.

Standard Definitions of Electrical Terms

The Institute was made sponsor for a glossary of electrical engineering terms, under the auspices of the A.S.A. in 1928. Some 30 scientific and engineering societies and organizations are represented on the sectional committee, the chairman of which is Prof. A. E. Kennelly, and the secretary, Mr. H. E. Farrer. The committee is divided into 18 subcommittees with the following chairmen: Messrs. H. L. Curtis, C. V. Christie, R. C. Sogge, H. E. Ruggles, H. D. James, J. F. Meyer, C. H. Sanderson, J. H. Davis, E. B. Paxton, F. M. Farmer, C. H. Sharp, G. W. Vinal, W. H. Martin, H. Pratt, M. G. Lloyd, and W. Wilson.

The personnel includes a total of about 120 members; including the experts consulted in the work, a personnel of more than 300 members are engaged. The numerical classification adopted was by group, section, and term numbers, designed to correspond with those proposed by the nomenclature of the International Electrotechnical Commission.

The sectional committee brought in a report which was printed by the Institute in August 1932. This report included more than 3,000 terms. The published report is in process of amendment and amplification prior to being submitted for acceptance by the coöperating organizations and the American Standards Association.

Summary

It has been pointed out that almost from its foundation 50 years ago, the Institute has actively engaged in standardization. It has done this through appointing many of its members to service on committees of standardization, and by expending a very appreciable share of its revenue on the publication of the results. It also has fostered many papers and discussions.

The Institute's standardization work may be divided into 3 categories:

1. Work on units, standards definitions, and nomenclature relating to basic sciences underlying electrical engineering.
2. Work on similar projects relating to applied science, engineering, and technology.
3. Work on projects relating to production and manufacture connected with electrical engineering.

These 3 classes of standardization may briefly be called: (1) basic, (2) technical, and (3) manufacturing standardization. Each is so important to the welfare of engineering, that the question of their relative importance to the Institute becomes insignificant.

1. The Institute's basic standardization, relating mainly to the sciences of physics, chemistry, and mathematics, has been carried on in large measure through the International Electrotechnical Commission (I.E.C.) and the International Commission on Illumination (I.C.I.), such work being mostly of an international character. It also has carried on such work through international electrical congresses, and through special committees of its own and allied societies dealing with basic subjects.
2. The Institute's technical standardization, relating to engineering practice, has been carried on largely through its standards committee, which was appointed in 1898 and is still actively at work. It has dealt principally with standard definitions, behavior, and tests of energy transporting and transforming machinery and apparatus, as used in the various branches of electrical engineering.
3. The Institute's share in manufacturing standardization, relating mainly to economical production, has been conducted principally through the Electrical Standards Committee, an organization representing the entire electrical industry, and the American Standards Association (A.S.A.), an organization representing all industries connected with engineering.

It is interesting to observe that the Institute's basic standardization was first in order of development, going back to 1890. Its technical standardization came next, the standards committee having been appointed in 1898. The participation in manufacturing standardization did not take effect until about 1920. There is every reason to expect that the Institute's future will be as closely associated with standardization along all 3 lines, as has been its past.